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独叶草属的胚胎学及其系统学意义*

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KINGDONIA, EMBRYOLOGY AND ITS SYSTEMATIC SIGNIFICANCE

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Abstract The embryological studies show that *Kingdonia* is similar to *Circaeaster* while different from other members of the Ranunculales (sensu Takhtajan, 1980) in development of endosperm and embryo. We consider that there is close systematic relationship between *Kingdonia* and *Circaeaster*.

Key words *Kingdonia*; Embryology; Systematic relationship

Kingdonia, with only one species, *K. uniflora* Balf. f. et W. W. Smith, is special in many characteristics, for instance, the dichotomous leaf venation, like that of *Circaeaster*. The embryological characteristics of *Circaeaster* are unique(Hu & Yang, 1987; Junell, 1931), while the embryology of *Kingdonia* remains unknown except ovule, gametophyte, fertilization, and early endosperm development (Mu, 1984, 1983).

1 Materials and Methods

The materials, collected from the Taibai Mountains, Shaanxi Province from May to August, 1994 and 1995, were fixed in FAA, dehydrated in the alcohol series, infiltrated with xylene and embedded in paraffin wax. The embedded materials were sectioned at 6～8 μm thick, stained with safranin and counter-stained with fast green, or stained with iron-alum haematoxylin and counter-stained with orange G. The contents of endosperm cells were stained by PAS reaction, Sudan black B, and Coomassie brilliant blue.

2 Observations

The structure of ovules and development of embryo sacs have been already reported (Hu & Tian, 1985; Mu, 1984). In this paper we focus on the development of embryos and endosperm, and the changes of integuments, nucellus, sterile megaspores and antipodal cells during that developmental stage were also briefly described.

After fertilization, the primary endosperm nucleus divided longitudinally into 2 longitudinally elongated cells (Plate Ⅰ: 2), which soon divided transversely into 4 cells, and the zygote divided at this time (Plate Ⅰ: 3～5). These endosperm cells divided both transversely and longitudinally into multi-celled endosperm (Plate Ⅰ: 6) and then began to differentiate in the following process. The cells near the chalaza became larger, irregular (Plate Ⅰ:

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8), with no starch grains stored in them during the whole developmental process (Plate Ⅰ: 11), and finally moved to the side near the hilum because of different dividing rates of endosperm cells in different position (Plate Ⅰ: 10). This part of the endosperm appeared fan-shaped in a longitudinal section (Plate Ⅰ: 10) and crescent in a cross section (Plate Ⅰ: 13). Other endosperm cells did not change in shape (Plate Ⅰ: 8) and contained starch grains (Plate Ⅰ: 11) and occupied the main part of endosperm (Plate Ⅰ: 11). At the late torpedo-like embryo stage, the endosperm consisted of densely arranged parachymous cells, and the cells of endosperm surface were regular and subsquare in shape with thicker outer walls (Plate Ⅰ: 12).

The embryogeny of *Kingdonia* followed the Caryophyllad type of Johansen (1950) (Plate Ⅱ: 1~5) with slight differences between the two: in *Kingdonia*, the second or the third proembryo cell under the terminal cell divided longitudinally first (Plate Ⅱ: 6,7), and then other cells, except the terminal and the basal cell, divided in the same way (Plate Ⅱ: 8). The proembryo finally developed into a typical globular embryo (Plate Ⅱ: 13) via the stick-like (Plate Ⅱ: 9) and the small-globular embryo stages (Plate Ⅱ: 10~12). More than 99% of fruits fall off at the stage of globular embryo, while in the persistent fruits, seed continually developed till the embryo was at its late torpedo-like stage (Plate Ⅱ: 14). The torpedo-like embryo was with a vase-like body and a slender, longer stalk (Plate Ⅱ: 14).

The integument, sterile megaspores, nucellus and antipodal cells underwent some special changes during the embryogeny of *Kingdonia*. Before fertilization, the integument covered 1/3 part of the nucellus (Plate Ⅰ: 1), while after fertilization, it elongated to cover the nucellus (Plate Ⅰ: 2,5). Simultaneously, inner epidermal cells of integument near the micropyle elongated radically to form a palisade-like structure (Plate Ⅰ: 2, 4, 5) which was out of shape (Plate Ⅰ: 6) at the 2~3-celled proembryo stage. In the following process, the integument became out of shape (Plate Ⅰ: 9) and degenerated and then disappeared completely (Plate Ⅰ: 10~13). This made the seed without testa (Plate Ⅰ: 10, 13). Most of nucellar cells disappeared after fertilization, but the cells surrounding the sterile megaspore (s), which did not disappear (Plate Ⅰ: 1, 5), were persistent (Plate Ⅰ: 2, 5). These nucellar cells formed an obturator-like structure with the sterile megaspore(s) in the micropyle (Plate Ⅰ: 2, 5). This structure degenerated at 2~3-celled proembryo stage (Plate Ⅰ: 6). The antipodal cells were persistent and enlarged, and their cytoplasm became dense (Plate Ⅰ: 2, 5, 6, 8) after fertilization and did not disappear till the stick-like embryo stage.

3 Discussion

3.1 The embryogeny of *Kingdonia* is similar to that of *Circaeaster* (Hu & Yang, 1985). In these two genera, the first longitudinal cell division of proembryo occurs in the second or the third cell under the terminal cell, differing from any variation of the Caryophyllad type, and thus we named this variation a *Kingdonia* variation.

The 2-celled endosperm of *Kingdonia* undergoes cell division immediately after the first division of the primary endosperm nucleus, and therefore the endosperm of *Kingdonia* is cellular. This differs from the observation of Mu (1984).

3.2 The similarities in embryology among *Kingdonia*, *Circaeaster* and the other members of the Ranunculales are shown in Table 1.

Table 1 The embryological similarities between *Kingdonia*, *Circaeaster* and other members of Ranunculales

Characteristics		*Kingdonia*	*Circaeaster*	other Ranunculales
embryo	development type	subtype Kingdonia under Caryophyllad type	subtype Kingdonia under Caryophyllad type	Onagrad[3),6)], seldom Solanad[7)] type or both[1)]
	embryo stage when fruits fallen	late torpedo-like stage	completely differentiated[5)]	globular stage or completely differentiated[1),4),6),12)]
endosperm	development	cellular, first division of primary endosperm nucleus longitudinal	cellular, first division of primary endosperm nucleus longitudinal [5),8)]	only cellular in Lardizabalaceae with primary endosperm nucleus dividing transversal[2),3),11)]
	differentiation of endosperm cells	differentiating into 2 parts and the part without starch grains at one side of seed	differentiating into 2 parts and the part without starch grains at one end of seed[5),8)]	undifferentiated
	cell wall	thin	thick[5),8)]	thin
	outer wall of epidermal cells	thickened	thickened[5)]	not thickened
integument change		covers 1/3 part of nucellus before fertilization; after that, elongating and then disappearing; seeds without testa	covers 1/3 of nucellus before fertilization; after that, elongating and then disappearing; seeds without testa[5),8)]	covers the whole nucellus before fertilization and developing into testa after fertilization
palisade-like stucture		occuring in inner epiderm	no[5),8)]	occuring in both inner and outer integuments in *Nandina* of Berberidaceae[10)]
sterile megaspore		1~2 persistent	none persistent[5)]	not reported
obturator-like structure in micropyle		formed by sterile megaspore(s) & persistent nucellar	no[5)]	not reported
antipodal cells		persistent	persistent[5)]	persistent[1),3),9)]

1) Bhandari, 1968; 2) Bhatnagar, 1965; 3) Davis, 1966; 4) Engell, 1995; 5) Hu & Yang, 1987; 6) Jalans, 1963; 7) Johansen, 1950; 8) Junell, 1931; 9) Sastri, 1969; 10) Schnarf, 1931; 11) Swamy, 1954; 12) Tamura, 1965

3.3 Based on the synthetic analysis of embryological characteristics, we consider that *Kingdonia* is more closely related to *Circaeaster* than to the other members of the Ranunculales. This consideration agrees with the results of the studies on pollen grains (Nowicke & Skvarla, 1982), chromosomes (Kong & Yang, 1997), leaf venation (Ren *et al*., 1997; Ren & Hu, 1996) and nuclear ribosomal DNA (Oxelman & Liden, 1995).

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Explanation of plates

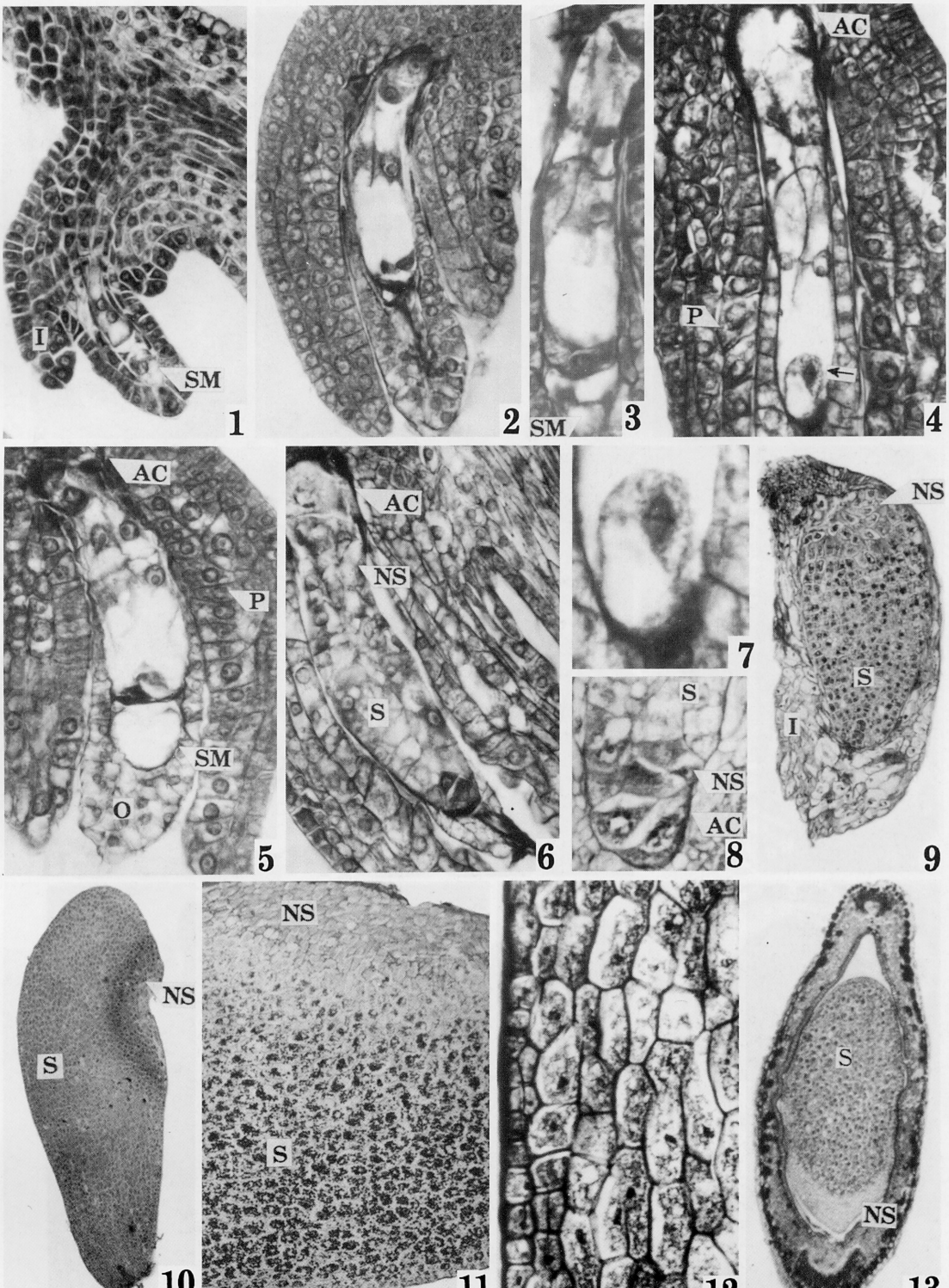
Plate Ⅰ Embryology of *Kingdonia* 1. Longitudinal section of enlarged part of an ovary, showing integument(Ⅰ) and a persistent sterile megaspore(SM)(×250). 2. Longitudinal section of 2-celled endosperm(×400). 3~5. 4-celled endosperm: 3. Showing the persistent sterile megaspore(SM)(×400); 4. Showing the first division of zygote(arrow), persistent antipodal cells(AC) and palisade-like structure of integument(P)(×400); 5. Showing persistent antipodal cells(AC), obturator-like structure(O), Palisade-like structure(P) of integument and persistent sterile megaspore(SM)(×450). 6. Multi-celled endosperm at 3-celled proembryo

stage and persistent antipodal cell(AC)(×250). 7. Enlarged part shown in Fig. 4, showing the first division of zygote(×500). 8. Enlarged part of endosperm near chalaza, showing differentiation of endosperm(NS: the part without starch grains in cells, S: the part with starch grains in cells, the same bellow)(×300).9. Longitudinal section of a young seed in 2-series-celled proembryo stage, showing differentiated endosperm and degenerating integument(Ⅰ)(×35). 10. Same as Fig. 9, but at stick-like proembryo stage, showing differentiation of endosperm and seed without testa(×30). 11. Enlarged part of endosperm stained by PAS reaction at tropedo-like embryo stage, showing the part without starch grains in cells(NS) in one side of seed(×200). 12. Enlarged part of endosperm at tropedo-like embryo stage, showing the thicker outer wall of epidermal cells(×400). 13. Transversal section of a fruit, showing the seed without testa, and the position and shape of different part of endosperm(×30).

Plate Ⅱ Embryology of *Kingdonia*: Proembryo 1. 2-celled stage(×400). 2. 3-celled stage(×400). 3. 4-celled stage(×350). 4. 5-celled stage(×400). 5. 6-celled stage(×300). 6. 9-celled stage, showing the second or third cell under terminal cell divides longitudinally(arrow)(×300). 7. Same as Fig. 19. ×320). 8. Club-shaped embryo, showing the proembryo cells dividing longitudinally except the terminal and basal cell (×300). 9. Club-shaped embryo(×300). 10～14. Small globular embryo of different development degree (10. ×280; 11. ×300; 12. ×280); 13. Globular embryo(×350); 14. tropedo-like embryo(×280).

摘要 独叶草属的胚乳发育为五福花型,其早期分化属细胞型;胚胎发育为石竹型下的独叶草亚型;珠被内层的部分细胞形成栅栏组织状,最后消失或近于消失;反足细胞宿存,部分不育大孢子宿存并和部分珠心组织一起形成珠孔塞状结构。这些性状表明它与星叶草属间的相似性要大于与毛茛目其它成员间的相似性。

关键词 独叶草属; 胚胎学; 亲缘关系



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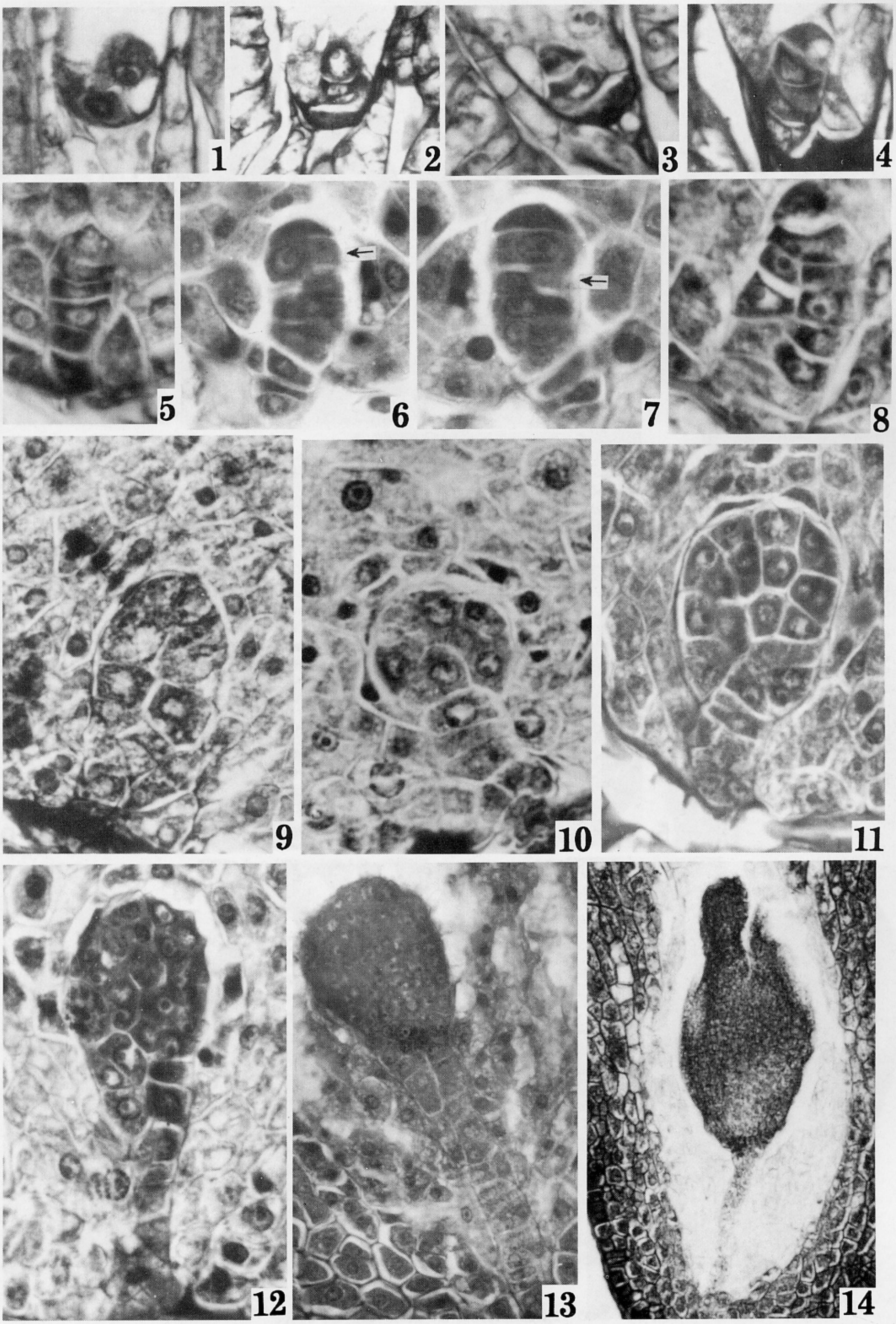

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